Naval Fuels & Lubricants
Cross Functional Team
Test Report

Impact of 50% Alcohol to Jet Blends on Aviation Turbine Fuel Coalescence - Navy Coalescence Test

NF&LCFT REPORT 441/15-001

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LIST OF ACRONYMS/ABBREVIATIONS

ATJ.. Alcohol to Jet

CFT .... Cross Functional Team

IAW.. in accordance with

NATOPS .... Naval Air Training and Operating Procedures Standardization

NCT.. Navy Coalescence Test

PPM.. parts per million (either by mass or volume)

PPMV.. parts per million by volume

PSEF .... Propulsion Systems Evaluation Facility

DEFINITIONS

Coalescence............. the ability to shed (separate) water from fuel

Dissolved Water......water that is in solution with the fuel (i.e. at or below the saturation point)

Element ....a separation device comprised of a filter/coalescer and separator

Free Water ....water in a multi-fluid stream which is above the fluid’s saturation point (not dissolved water)

Saturation point.......the total water concentration at which all water present in the fuel is dissolved in the fuel and the further addition of water will result in the presence of free water. The saturation point is dependent on the chemical composition of the fuel and trends directly with temperature.

EXECUTIVE SUMMARY

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The Navy Colaescence Test (NCT) is a level II fit-for-purpose test in the Navy's alternative fuels qualification protocol, Navy SWP44FL-006: Naval Fuels & Lubricants Cross Functional Team (CFT) Shipboard Aviation Fuel, JP-5, Qualification Protocol for Alternative Fuel/Fuel Sources[1].

Alcohol to Jet (ATJ) fuel is an alternative sourced aviation fuel that is currently being evaluated. ATJ fuels are synthetic paraffin fuels produced from alcohols (isobutanol or n-butanol). Sugars, corn, grass/wood/biomass, and power plant/industrial CO_2 are all potential ATJ feedstocks. ATJ fuels are comprised of a mixture of C8, C12, and C16 paraffins.

The 50/50 JP-5/ATJ by volume fuel blend's ability to coalesce free water was evaluated by performing a Navy Coalescence Test (NCT). The NCT simulates the performance of a full-scale filter-separator system through the use of a small-scale fuel system and specially manufactured scaled down filter/coalescer and separator. The NCT is designed to predict the effects of new additives and fuels on filter-separator systems currently in use by the fleet. Due to the small size of the system, no conclusions can be made as to the effects of the new additives or fuels on solid contaminant removal. However, the effects of free water coalescence and removal by filter-separators may be determined.

After 80 hours of testing, 50/50 JP-5/ATJ met the acceptable performance criteria— no more than three consecutive hours of filter-separator effluent free water concentrations greater than or equal to 100 ppm by volume (ppmv). On average, 87% of the 205 ppmv free water injected was removed by the filter-separator and only one effluent sample contained greater than 100 ppmv free water. Despite the average effluent sample exceeding the NATOPS Aircraft Refueling Manual NAVAIR 00-80T-109[2] maximum free water concentration of 10 ppm, it can still be concluded that 50% ATJ has no significant impact on free water coalescence and removal. Due to the small scale nature of the NCT, factors not typically of concern during full-scale testing or rountine sampling such as agglomeration of free water droplets and precision of the water determination test method are exacerbated. These factors were accounted for when selecting the acceptable performance criteria as any gross reduction in filter-separator performance would result in failure to meet this criteria. Therefore it is recommended that 50/50 JP-5/ATJ by volume be approved for full-scale filter/coalescer-separator single element testing.

Impact of 50% Alcohol to Jet Blends on Aviation Turbine Fuel Coalescence- Navy Coalescence Test

1.0 BACKGROUND

In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The Secretary set a goal of operating with at least 50% of energy consumption coming from alternative sources by 2020. He also set forth the goal of demonstrating a Great Green Fleet, operating on 50% alternative fuel, by 2012 and deploying by 2016. The use of alternative/petroleum sourced aviation fuel blends is a critical component to achieving these goals. The alternative sourced fuels will come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. The Navy Colaescence Test (NCT) is a level II fit-for-purpose test in the Navy's alternative fuels qualification protocol, Navy SWP44FL-006: Naval Fuels & Lubricants CFT Shipboard Aviation Fuel, JP-5, Qualification Protocol for Alternative Fuel/Fuel Sources[1]

Alcohol to Jet (ATJ) fuel is an alternative sourced aviation fuel currently being evaluated. ATJ fuel is a synthetic paraffin fuel produced from the oligermization and hydroprocessing of alcohol precursors (isobutanol or n-butanol). Sugars, corn, grass/wood/biomass, and power plant/industrial CO_2 are all potential ATJ feedstocks. ATJ fuels are comprised of a mixture of C8, C12, and C16 paraffins. The degree of chemical branching is dependent on the alcohol starting material used.

The US Navy is in the process of evaluating 50% (by vol) ATJ fuel blends to determine their impacts on performance, handling and safety. In order for a 50% JP-5 and 50% ATJ by volume fuel blend (abbreviated 50/50 JP-5/ATJ) to be considered a drop-in replacement for petroleum derived aviation fuel, the blend must be compatible with all current fuel system components including filter-separator systems.

Filter-separators are used onboard naval vessels and at shore stations to reduce solid and free water contamination in aviation fuel to acceptable levels. Naval Air Training and Operating Procedures Standardization (NATOPS) Aircraft Refueling Manual NAVAIR 00-80T-109[2] allows a maximum free water concentration of 10 ppmv in JP-5. Per section 5.11.4 of MIL-STD-3004D[3], for aviation turbine fuel to be acceptable for fueling aircraft it shall contain no more 10 ppm by volume (ppmv) free water. The NCT is designed to simulate a full-scale filter-separator system so that a fuel's ability to coalesce water can be evaluated on a small-scale (150 gallons to complete a NCT vs. several thousand gallons to complete a full-scale filter/coalescer-separator single element test).

2.0 OBJECTIVE

To determine the effects of 50% ATJ (by vol.) on the coalescence properties of petroleum derived JP-5 by comparing the influent and effluent total water concentrations of a scaled down filter/coalescer and separator filtration system.

3.0 APPROACH

3.1 Test Overview

Testing was conducted in accordance with (IAW) Appendix A-12 of SWP44FL-006 Version 1.2[1]. The test is comprised of saturating dry fuel with water (via wet N_2 sparging), injecting 250 ± 50 ppmv of free water upstream of a filter/coalescer and separator element, and removing the water via the element. The total water concentration in the fuel is measured at each of these three locations per test procedure ASTM D6304-Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration[4]. Due to the low flow rate of 100 mL/min, direct free water measurements IAW ASTM D3240-Standard Test Method for Undissolved Water In Aviation Turbine Fuels[5] are not feasible. The total water concentration of three samples from the influent and effluent of the filter-separator capsule and one sample of water saturated fuel are measured each hour. By measuring and graphing the total water and free water concentrations at these three locations, the effects on coalescence can be determined. When coalescence is unaffected, the water levels in the saturated fuel and at the outlet of the element are close in value (i.e. little free water). When coalescence is compromised, very little of the free water injected is removed and the water levels at the inlet and outlet of the element are close in value. Differential pressure across the coalescer is also recorded to ensure the differential pressure does not exceed 15 psi at which point filter/coalescer and separator performance is compromised. The standard test duration is 80 hours and the fuel flow rate is 100% of the element's rated flow capacity, 100 mL/min. A flow schematic for the NCT rig is shown in Figure 1.

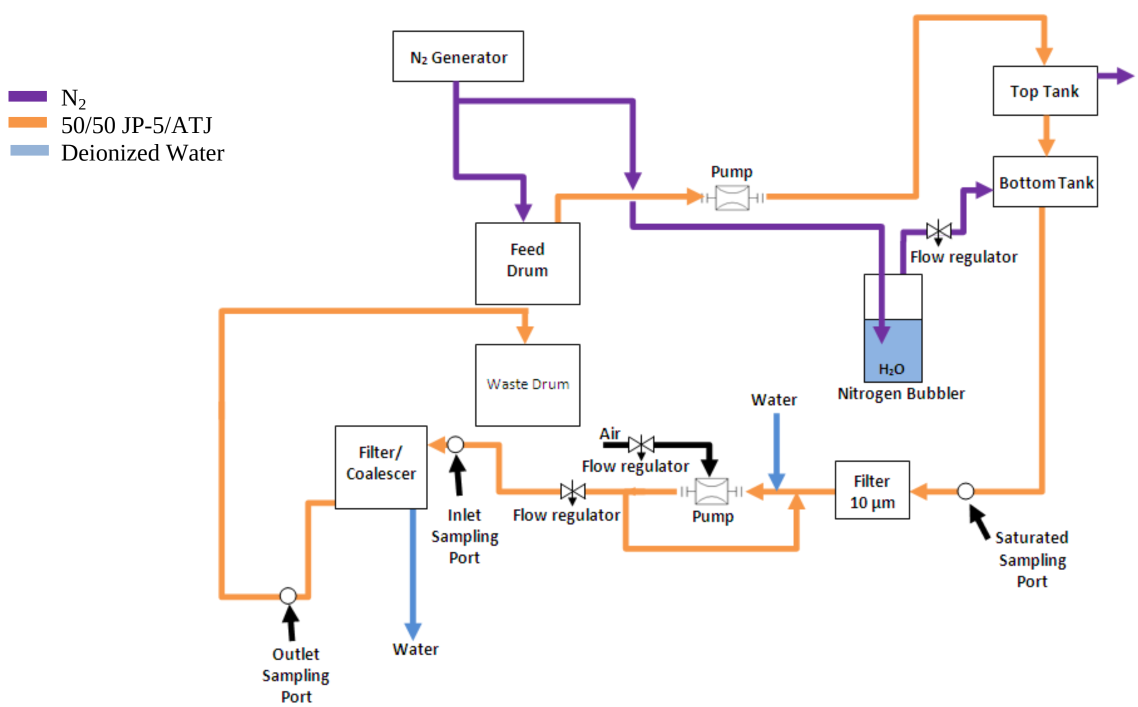

Figure 1: NCT Flow Schematic

3.2 Test Fuel

The effects of ATJ on filter-separator performance were determined by testing a 50/50 JP-5/ATJ by volume fuel blend. The ATJ component of the 50/50 JP-5/ATJ fuel blend was manufactured by Gevo® using an isobutanol precursor and procured by the United States Air Force. The ATJ was transferred from Wright-Patterson Air Force Base to the Propulsion Systems Evaluation Facility (PSEF) located at Naval Air Station Patuxent River, MD in April 2014. ATJ was then blended with JP-5 at 1:1 by volume to produce a 50/50 blend. The test fuel met all MIL-DTL-5624V[6] physical and chemical properties except for density at 15°C and flash point (see Appendix A). Both of these properties fell below the JP-5 limits due to the lower density and flash point of ATJ (the test fuel's density at 15°C and flash point met the requirements of JP-8 as defined in MIL-DTL-83133H[7]). However, these properties do not impact the validity of this test as any improvement in fuel-water separation due to the lower density fuel is negligible (less than 1% difference between the density of the test fuel and the minimum JP-5 spec requirement).

Prior to testing the 50/50 blend test fuel was water washed, recirculated through a filter-separator, and then clay treated to remove additives (microseparometer rating >95), sediment (<0.26 mg/L), and free water (<5 ppmv). The additives listed below were added IAW Appendix B. The additized fuel was then stored in three 55 gallon epoxy lined drums for testing on the NCT rig.

A. Static Dissipater Additive, Stadis 450® (Octel America, Newark DE) at a concentration of 2.0 ±0.2 mg/L.
B. Fuel System Icing Inhibitor in accordance with MIL-DTL-85470 at a concentration of 0.15 percent (by volume) ±0.01 percent.
C. Corrosion Inhibitor, DCI-4A in accordance with MIL-DTL-25017 at a concentration of 15 ±1 mg/L.

3.3 Acceptance Criteria

In order to successfully pass the NCT, the difference between the total water concentration of the saturated fuel and the fuel leaving the test element (i.e. free water) must be less than 100 ppmv. If this criterion is exceeded for four consecutive hours, the test will be reported as a failure. The 100 ppmv limit has been chosen because it allows for variations in the fuel sample, system disturbances (i.e excess water injection and incomplete saturation), and small-scale specific factors that may be insignificant during full-scale testing such as agglomeration of free water droplets and differences in precision between ASTM D6304 and ASTM D3240. However, this limit is low enough that any gross failure in coalescence will be readily apparent. The differential pressure across the capsule which houses the filter and separator shall not exceed 15 psi at any point during the test. If the differential pressure exceeds 15 psi the fuel fails the NCT.

4.0 DISCUSSION

The average total water concentration of the saturated fuel stream and the filter-separator influent and effluent fuel streams can be found in Figure 2. At test hours 20, 42, and 63 test data is excluded due to test rig issues which prevented test data from being collected.

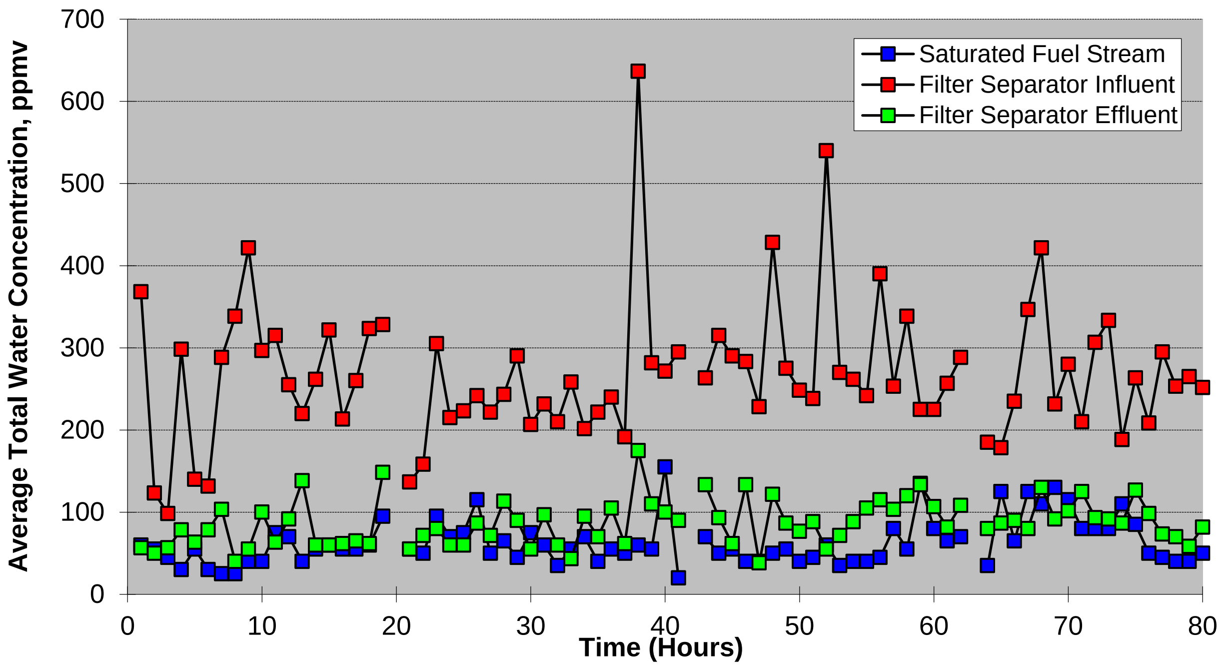

Figure 2: Average Total Water Concentration: Saturated Fuel Stream, Filter Separator Influent and Effluent

As can be seen in Figure 2, at some test points the total water concentration of the filter-separator effluent are below the measured saturation point of the test fuel. This can be associated to excessive water saturation (i.e. addition of free water). To more accurately estimate the concentration of free water in the effluent stream, the saturation point of the 50/50 JP-5/ATJ is calculated to be equal to 63±6 ppmv where the 63 ppmv and ±6 ppmv variation correspond to the average saturated tank concentration measured and the 95% confidence interval, respectively. Since the fuel temperature varied between 68°F and 72°F throughout the evaluation period, 63±6 ppmv is a reasonable estimate of the test fuel's water saturation concentration as any variations in water saturation point due to temperature would be less than the reproducibility associated with ASTM D6304[4] and fall within this ±6 ppmv range. A separate laboratory test was completed to validate the 63 ppmv water saturation point. From the laboratory test described in Appendix C, it was determined that the 50/50 JP-5/ATJ test fuel had a water saturation point of 57 ppmv, which falls within the 95% confidence interval measured during the NCT. Figure 3 excludes the inlet total water concentrations to better illustrate the differences between the saturated and effluent fuel streams' total water concentrations. As can be seen in Figure 3 the total water concentration of the saturated fuel stream varied between 20 and 155 ppmv. Since all of the test fuel came from the same batch and the the temperature of the fuel varied by no more than 4°F, this broad range is not representative of the saturation point of the fuel. However the average of these values, 63 ppmv, is a reasonable estimate of the saturation point of the fuel due

to the large sample size and results of the laboratory water saturation point test. In Figure 3 it can also be seen that the total water concentration of several of the filter-separator effluent samples fell below the 63 ppmv water saturation point. This is likely the result of sample variations due to incomplete mixing. Based on the filter-separator influent concentrations which prove free water was injected and filter-separator's limitation to only remove free water, effluent total water concentrations below 63 ppmv have been corrected to 63 ppmv for this analysis.

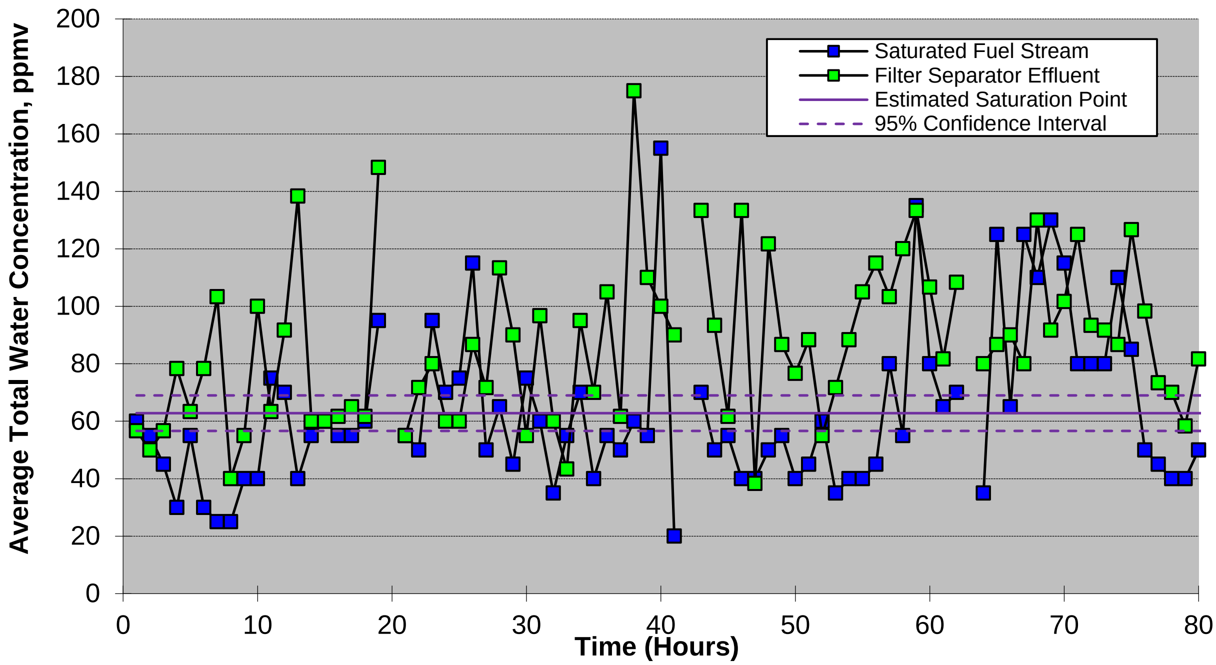

Figure 3: Average Total Water Concentration: Filter-separator Effluent and Saturated Fuel Stream

Based on a water saturation point of 63 ppmv, the amount of free water injected by the syringe pump (Influent Total Water Concentration– Saturation Point) and coalesced by the filter-separator system (Influent Total Water Concentration – Corrected Effluent Total Water Concentration) is shown in Figure 4. On average, 205 ppmv free water was injected into the fuel stream and 179 ppmv free water was coalesced (87% free water removal).

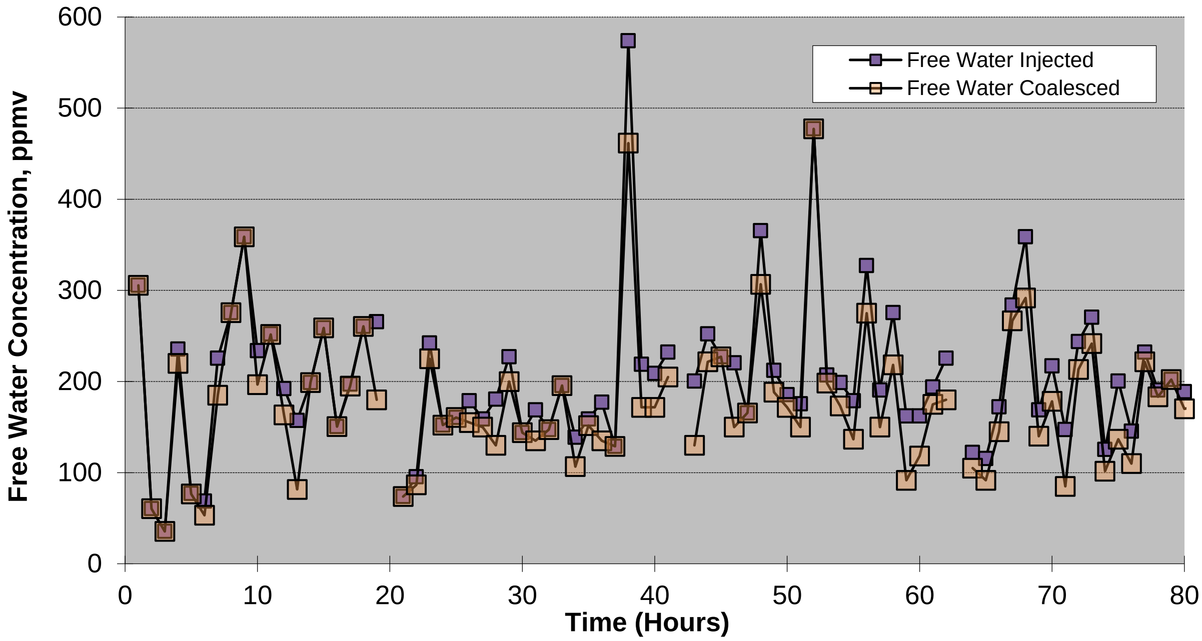

Figure 4: Concentration of Free Water Injected and Coalesced

As can be seen in Figure 5, an effluent free water concentration greater than 100 ppmv was measured only once at test hour 38. The average free water concentration measured at the outlet of the filter-separator was 26 ppmv (std dev= 25 ppmv). At no point during the test did the differential pressure across the filter-separator capsule exceed 2 psi. Therefore the 50/50 JP-5/ATJ fuel blend satisfactorily met all NCT acceptance criteria stated in Section 3.3 and has no significant impact on free water coalescence. All test data can be found in Appendix D.

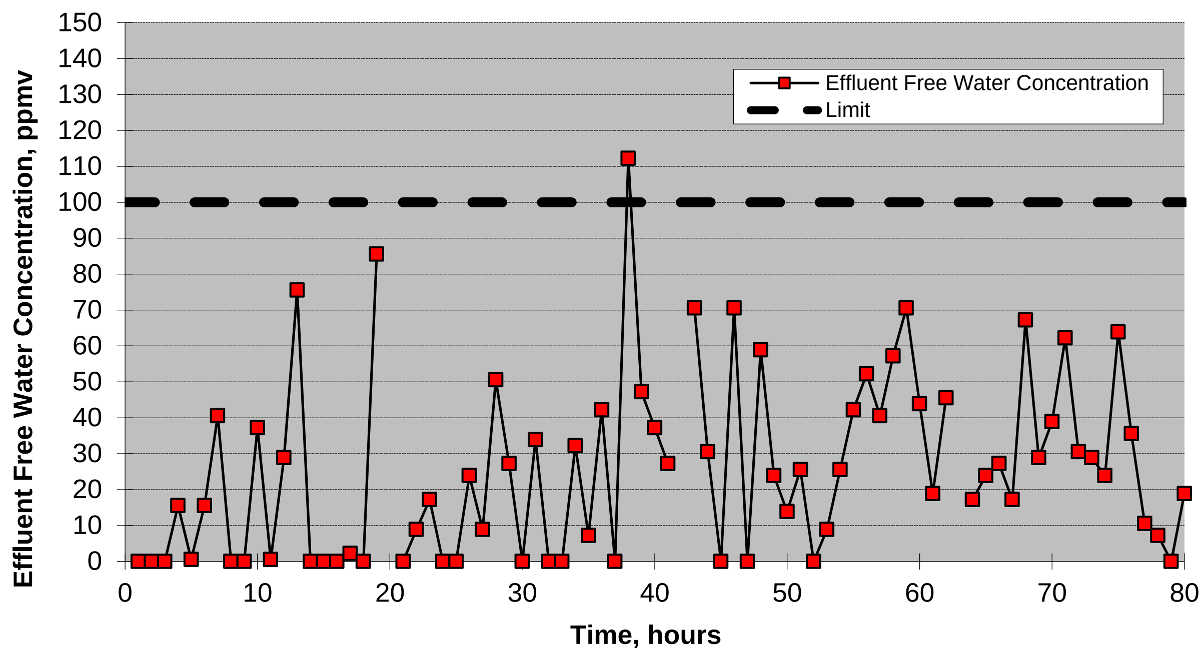

Figure 5: Effluent Free Water Concentration

5.0 CONCLUSIONS

The 50/50 JP-5/ATJ fuel blend met the acceptable performance criteria stated in section 3.3. Based on this analysis, ATJ does not adversely affect JP-5 water coalescence when blended at a ratio up to 50% by volume.

6.0 RECOMMENDATIONS

It is recommended 50/50 JP-5/ATJ by volume be approved for full-scale filter/coalescer-separator single element testing so that coalescence results from this test can be confirmed and the effect of sediment laden 50/50 JP-5/ATJ on filter-separator performance studied.

7.0 REFERENCES

1. United States Navy- Naval Fuels & Lubricants CFT. *SWP44FL-006: Naval Fuels & Lubricants CFT Shipboard Qualification Protocol for Shipboard Aviation Fuel, JP-5, Fuel/Fuel Sources Version 1.2*. October 2011.
2. United States Navy. *NATOPS Aircraft Refueling Manual NAVAIR 00-80T-109*
3. U.S. Department of Defense. *MIL-STD-3004D Department of Defense Standard Practice Quality Assurance/Surveillance for Fuels, Lubricants and Related Products.* October 2014
4. ASTM International. *ASTM D6304-07: Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration*, August 2007
5. ASTM International. *ASTM D3240-11: Standard Test Method for Undissolved Water in Aviation Turbine Fuel*, March 2011
6. MIL-DTL-5624V, *Detail Specification: Turbine Fuel, Aviation, Grades JP-4 and JP-5*
7. MIL-DTL-83133H, *Turbine Fuel, Aviation, Kerosene Type, JP-8 (NATO F-34), NATO F-35, and JP-8+100 (NATO F-37)*

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APPENDIX A. TEST FUEL CHEMICAL AND PHYSICAL PROPERTIES

Test (Units)	Method	Minimum	Maximum	50/50 JP-5/ATJ
Color, Saybolt	D6045	Report		14
Total Acid Number (mgKOH/g)	D3242		0.015	0.003
Aromatics (volume %)	D1319	8.0 [a]	25.0	9.3
Sulfur, Mercaptan (mass %) or,	D3227		0.002	0.001
Doctor Test	D4952		Negative	-
Sulfur, Total				
XRF (mass %), or	D4294		0.20	0.07
UV Fluorescence (mg/kg)	D5453		2000	-
Distillation	D86			
Initial (°C)		Report		172
10% Recovered (°C)			205	183
20% Recovered (°C)		Report		187
50% Recovered (°C)		Report		196
90 % Recovered (°C)		Report		235
End Point (°C)			300	263
Residue (volume %)			1.5	1.5
Loss (volume %)			1.5	0.1
Flash Point (°C)	D93	60.0		57.0[b]
Density at 15 °C (kg/L)	D4052	0.788	0.845	0.784[b]
Freezing Point (°C)	D5972		-46	-58
Viscosity at -20 °C (mm^2/s)	D445		8.5	5.0
Net Heat of Combustion (MJ/kg)	D4809	42.6		43.4
Ignition Quality, Derived Cetane Number	D6890	Report		35.7
Hydrogen Content (mass %)	D7171	13.4		14.5
Smoke Point (mm)	D1322	19.0		27.9
Copper Strip Corrosion, two hours at 100 °C	D130		1	1a
Thermal stability				
Pressure Drop (mm Hg)	D3241		25	0
Heater Tube Deposit			<3	1
Existent Gum (mg/100 mL)	D381		7.0	5.0
Particulate Matter (mg/L)	D5452		1.0	0.2
Filtration Time (minutes)	MIL-DTL-5624V		15	6
Micro Separometer Rating	D7224	[c]		63[c,d]
Fuel System Icing Inhibitor (volume %)	D5006	0.10	0.15	0.13[d]

[a] Requirement only applies to fuels containing synthetic blending components.
[b] These properties meet the JP-8 MIL-DTL83133H specification limits but not the JP-5 MIL-DTL-5624V specification limits.
[c] Value is dependent on additives in the fuel. No minimum requirement for fuels containing SDA, as SDA is not approved for use in JP-5
[d] MSEP and FSII values of test fuel measured after adding additives and prior to testing (sect 3.2)

APPENDIX B. METHOD FOR INJECTING FUEL ADDITIVES TO THE TEST FLUID

B.1 SCOPE

B.1.1 Scope. This appendix details the method to be used for injecting the test fluid with the required additives.

B.2 PROCEDURE

B.2.1 Test fuel cleanup. The test fluid shall be filtered until an AquaGlo reading of 5 parts per million by volume or less is obtained when tested in accordance with ASTM-D3240. The test fluid shall then be clay filtered until a Micro-Separometer (MSEP) Surfactants value of 95 or greater is obtained when tested in accordance with ASTM-D3948. All filtration equipment shall be bypassed before adding the additives.

B.2.2 Additive injection. The test fuel shall be inhibited according to the amounts specified in section 3.2. To determine the duration of recirculation needed to achieve a homogenous mixture of fuel and inhibitors, the following procedure shall be used. Inject additive A upstream of the main pump. The conductivity shall be measured at 5-minute intervals after the additive is introduced to the fuel. The elapsed time from the initial addition of the additive to the time when three successive conductivity measurements at 5-minute intervals are within ±20 pico Siemens/meter (pS/m) shall be noted as the mixing time. Additives B shall then be added in the same manner allowing the same mixing time. Next additive C shall be added allowing the same mixing time before beginning the test.

B.3 CAUTION

B.3.1 Handling of additives. Refer to manufacturer's safety data sheets for precautions to be taken while handling fuel inhibitors.

APPENDIX C. LABORATORY WATER SATURATION TEST

Scope: This procedure can be used to evaluate water solubility in aviation and diesel fuels.

Required Instrumentation⁄Equipment:

- 125 mL glass bottles
- Water Bath (or equivalent temperature chamber)
- Karl Fischer test instrument (per ASTM D6304)
- Transfer pipets
-

Fuel Required:
100 mL of test fuel

Required Reagents *I* Materials:
Deionized water

Test Procedure:

1. Add 25 mL of deionized water and 75 mL of fuel to a 125 mL glass bottle. Cap the bottle and place the sample in a water bath set to the test temperature.
2. Maintain the sample at test temperature for 24 hours.
3. The amount of water in the fuel layer should be determined using ASTM D6304, Procedure A. Draw an aliquot of the sample, using a transfer pipet, from the middle of the fuel layer for the test. Determine total water content immediately while the fuel sample is at the test temperature. Perform two additional measurements.
4. Report the average of the three replicate measurements as the water saturation point (ppm by volume)

APPENDIX D. TEST DATA

Table D-1. Test Data

Run Time	Temperature	Avg. F/S Influent	Avg. F/S Effluent*	Avg. Saturated*	ΔP
(test hour)	(°F)	(ppmv)	(ppmv)	(ppmv)	(psi)
1	71	368	57	60	1
2	71	123	50	55	1
3	71	98	57	45	1
4	71	298	78	30	3
5	71	140	63	55	3
6	71	132	78	30	1
7	71	288	103	25	1
8	72	338	40	25	1
9	72	422	55	40	1
10	72	297	100	40	1
11	71	315	63	75	1
12	71	255	92	70	1
13	69	220	138	40	1
14	69	262	60	55	1
15	70	322	60	60	1
16	70	213	62	55	1
17	70	260	65	55	1
18	68	323	62	60	1
19	68	328	148	95	1
20	[redacted]				
21	71	137	55	55	1
22	70	158	72	50	2
23	71	305	80	95	1
24	70	215	60	70	1
25	71	223	60	75	1
26	70	242	87	115	1
27	70	222	72	50	1
28	70	243	113	65	1
29	70	290	90	45	2
30	69	207	55	75	2
31	69	232	97	60	2
32	70	210	60	35	2
33	69	258	43	55	2
34	70	202	95	70	2
35	70	222	70	40	2
36	70	240	105	55	2
37	70	192	62	50	2
38	70	637	175	60	2
39	69	282	110	55	2
40	68	272	100	155	2

*Note measured test data is presented and may differ from figures in report due to corrections to the water saturation point, 63 ppmv.

Table D-1. Test Data (Continued)

Run Time	Temperature	Avg. F/S Influent	Avg. F/S Effluent*	Avg. Saturated*	ΔP
(test hour)	(°F)	(ppmv.)	(ppmv)	(ppmv)	(psi)
41	68	295	90	20	2
42					
43	70	263	133	70	0
44	69	315	93	50	0
45	70	290	62	55	0
46	70	283	133	40	1
47	71	228	38	40	1
48	69	428	122	50	1
49	69	275	87	55	1
50	70	248	77	40	1
51	69	238	88	45	1
52	69	540	55	60	1
53	70	270	72	35	1
54	70	262	88	40	1
55	70	242	105	40	1
56	68	390	115	45	1
57	69	253	103	80	1
58	69	338	120	55	1
59	68	225	133	135	1
60	69	225	107	80	1
61	70	257	82	65	1
62	70	288	108	70	1
63					
64	70	185	80	35	1
65	70	178	87	125	1
66	71	235	90	65	1
67	71	347	80	125	1
68	71	422	130	110	1
69	71	232	92	130	1
70	71	280	102	115	1
71	70	210	125	80	1
72	69	307	93	80	1
73	69	333	92	80	1
74	69	188	87	110	1
75	71	263	127	85	1
76	70	208	98	50	1
77	70	295	73	45	1
78	71	253	70	40	1
79	70	265	58	40	1
80	70	252	82	50	1

*Note measured test data is presented and may differ from figures in report due to corrections to the water saturation point, 63 ppmv.

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14. ABSTRACT
In October 2009, Secretary of the Navy Ray Mabus directed the Navy to decrease its reliance on fossil fuels. The objective of this test program is to ensure that all proposed alternative sourced fuels come from non-food sources and must be compatible with all existing hardware without compromising performance, handling or safety. Alcohol to Jet (ATJ) fuel is an alternative sourced aviation fuel currently being evaluated. ATJ fuels are synthetic paraffin fuels produced from alcohols (isobutanol or n-butanol). Sugars, corn, grass/wood/biomass, and power plant/industrial CO_2 are all potential ATJ feedstocks. ATJ fuels are comprised of a mixture of C8, C12, and C16 paraffins.

The Navy Coalescence Test (NCT) simulates the performance of a full-scale filter-separator system through the use of a small-scale fuel system and specially manufactured scaled down filter/coalescer and separator. The NCT is a level II fit-for-purpose test in the Navy's alternative fuels qualification protocol, Navy SWP44FL-006: Naval Fuels & Lubricants CFT Aviation Qualification Protocol for Alternative Fuel/Fuel Sources. After 80 hours of testing 50% JP-5/50% ATJ (by vol.) met the acceptable performance criteria— no more than three consecutive hours of filter-separator effluent free water concentrations greater than or equal to 100 ppm by volume. On average, 87% of the 205 ppmv free water injected was removed and only one effluent sample contained greater than 100 ppmv water. Therefore it is recommended 50% JP-5/50% ATJ be approved for full-scale single filter/coalescer element testing.

15. SUBJECT TERMS
Filter/coalescer, separator, Navy Coalescence Test, alternative fuels, 50/50 JP5/ATJ

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